WORLD COTTON RESEARCH CONFERENCE-3

COTTON PRODUCTION FOR THE NEW MILLENNIUM

WORLD COTTON RESEARCH - 3 - CONFERENCE

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Sustainable cotton production systems for the humid savannas of central Brazil

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ABSTRACT

Most Brazilian cotton is produced in the Cerrados, i.e. the humid savannas of Central Brazil. In this frontier region, a very dynamic and powerful agriculture is driven by the search for short term economic returns despite the absence of subsidies. Highly mechanized farmers first introduced large-scale monocultures dominated by soybean. More recently, cotton has become an attractive cash crop, despite difficult natural and economic conditions, resulting in irregular returns. Furthermore, the domination of monocultures, the use of disc tillage and high levels of inputs have resulted in soil and environmental degradation and less sustainable production systems. CIRAD, Brazilian research institutes, and various private partners (Maeda, Coodetec, Agronorte) have joined forces to find solutions resulting in significant and regular decreases in production costs while preserving soil fertility and the environment. Crop rotations, direct seeding under cover crops, and varietal testing within the most performing cropping systems, using a participatory approach, constitute the most promising avenues to achieve these objectives. This method, known as innovation-extension, allows the best producers to reach yields ranging from 3000 to more than 5000 kg/ha of seed cotton, while constantly increasing fiber quality, reducing production costs and risks and minimising the impact on the environment.

Introduction

The Brazilian cotton belt has shifted towards the humid tropics. At the beginning of the 1990s, the states of the central south (Paraná, São Paulo, Goiás and Minas Gerais) produced 540000 tons of fiber or 81% of the Brazilian production, the state of Paraná alone supplying 52% of national production (source: CONAB). At the same period, the state of Mato Grosso produced only 37000 tons or 5,5% of national production.

Over the past four years (1998-2002), the panorama of cotton production has been radically transformed (source: CONAB). The state of Mato Grosso has become Brazil's number one producer with 427000 tons of fiber in 2002 or 53% of national production. The majority of cotton production has thus shifted from southern regions with a subtropical climate (annual pluviometry ranging between 1000-1600 mm) to the humid tropical zone (higher pluviometry ranging from 1300 mm to more than 2000 mm concentrated in a shorter period of seven to eight months). This also involved a move from predominantly fertile dark-red ferralitic soils formed on basaltic rock in the south to the less fertile yellow-red and yellow-grey ferralitic soils formed on acid rock in the humid savannas (Figure 1).

This transfer of the cotton crop has, in reality, been a shift from the subtropical zone with a high potential for productivity, but which was greatly limited by the continuous practice of tillage and monoculture leading to the degradation of the soil's physical and biological properties (Figure 2; Séguy *et al*., 1998, 1997-2002) towards the wet tropical region where the soil is less fertile but where, over the last seven to ten years, land has been farmed using Direct seeding Mulch based Cropping systems (DMC). These farming systems are based on successions of two crops per year, including soybean or rainfed rice as main crops and maize, sorghum or millet as second crops (called "safrinhas"). With these successions, managed without tillage, the soil is totally protected from erosion and develops excellent physical and biological properties, which are extremely favourable for cotton growth (Séguy *et al.*, 1998, 2001a).

Research and development methodology

The "cerrados": a huge land reserve for agricultural development

The savannah of the Brazilian humid tropical zone (HTZ), called "cerrados", covers about 200 million hectares of which about half could be used for agricultural production (Figure 1). Currently only 50 million are actually used, essentially for pastures (80%). In the state of Mato Grosso, these lands were brought under cultivation in the late '70s under conventional tillage and soybean monoculture, rapidly leading to severe soil degradation because of erosive processes and excessive mineralisation of the soil's organic matter. Between 1986 and 2002, in order to answer rapidly and efficiently to this failure, CIRAD and its research and development partners created, developed and progressively disseminated more and more efficient DMC.

Building up innovation with a participatory on-farm approach

The development of DMC in developing countries, and more recently in Europe (South-North transfer), is based on a participatory innovation-extension methodology (Séguy *et al.,* 1998, 2001a). The assessment of a farmer's current cropping systems is taken as a starting point on which to build new operational systems (conception and modelling phase), which are then implemented at full scale (adaptation and validation phase). Well-modelled and implemented cropping systems provide a good support for process-based research in order to understand the differences of their functioning. The scientific research, which must first and foremost be useful, is thus connected to today's agricultural realities in order to provide farmers with suitable systems for tomorrow (Figure 3).

This *in situ* research, called “innovation-extension-training” (Séguy *et al.,* 1998, 2001a) uses a few experimental units and a net of regional reference farms. On the experimental units, jointly managed by researchers and farmers, the cropping systems are organised in a matrix on toposequences representing the physical environment (soil types and their state of degradation, dominant weeds, etc.). On the reference farms, influential and charismatic voluntary producers implement the systems they have selected in the experimental units, adapting them if need be; the group of reference farms is representative of regional variability (physical and socio-economic environment).

Starting from traditional cropping systems, the new systems are elaborated through the progressive, organised and monitored incorporation of more competitive factors of production. The setting up of matrices meets precise criteria, which allow the interpretation of the effects, both instant and cumulative, of the systems’ components in the course of time. Both the matrices and the reference farms are places of action, innovation and training where the agricultural models of the past, the present and the future are brought together. They constitute a valuable monitoring laboratory for more process-based scientific research and a breeding ground for the creation of diversified farming systems (from DMC restricted to grain and fiber production to farming systems including cattle and forestry productions).

Results and Discussion

Current cotton management practices are not sustainable

In Mato Grosso, farmers and extension agents implemented cotton crops by adapting part of the results of the previous research carried out by CIRAD between 1994 and 1999 in the less rainy regions of the south of the state of Goiás and the north of the state of São Paulo (Figure 4; Séguy *et al.*, 1998, 1999). The principle of sowing cotton on mulch is respected, but the rotation and no-tillage components are not applied. With soils improved by five to 10 years of continuous DMC (with annual successions of soybean + maize or millet), at first farmers record high yields: 3000 to 4500 kg/ha of cottonseed. But in the following years productivity falls despite the use of a high level of chemical input. The decrease in productivity is due to the effects of both monoculture and post-harvest tillage. Monoculture is justified by high investments in machinery and ginning equipment. Heavy tillage is used after stalk destruction in order to incorporate cotton residues and prevent regrowth; it is a preventive measure imposed by federal and state law in order to control pests and diseases such as *Aphis gossypii* (vector of the blue disease) and *Colletotrichum gossypii* var. *cephalosporioides* (responsible for ramulosis). Calcio-magnesium lime is also incorporated every two or three years jointly with cotton residues. The soil is finally pulverized by a disk harrow to incorporate the cover crop seeds sown broadcast at the beginning of the rainy season (mainly millet, sometimes sorghum). This system known as “*semi* direct seeding” momentarily re-exposes the soil to erosion, accelerates the mineralisation of soil organic carbon (S.O.C.) indicating annual C losses, brings back to the soil surface weed seeds allowing them to compete with cotton, and favours the development of nematodes. Furthermore, large quantities of fertilizers (150 to 160 kg/ha N + 180 to 200 kg/ha P_2O_5 + 200 to 260 kg/ha K_2O) and agrochemicals are used (in order to face increasing parasitic pressure by pests and cryptogamic diseases), resulting in very high production costs, ranging from 1300 to 1600 US $/ha, which is superior to land prices. In a region placed at a disadvantage by the long distances from seaports and the precarious state of transport infrastructures, economic risks linked to cotton production become considerable (Figure 5).

New diversified and sustainable DMC are available from research

In HTZ, between 1986 and 2002, taking as a starting point for their research the initial degrading system of soybean monoculture with tillage, CIRAD and its Brazilian partners have successively developed:

- Systems of two-year rotations with soybean and cereals (rice, maize) as annual single crops, with tillage;
- Systems of two-year rotations with “safrinhas” every two years, that is with the introduction every other year of a second crop in succession to the main crop, implemented in direct seeding on the residues of the main crop;
- Systems with two annual crops per year (main crop + second crop) entirely implemented in direct seeding without tillage;
- Systems with three annual crops per year ; the main crop (soybean or rice or maize) is followed by a “safrinha” that includes a cereal (maize, millet, sorghum, *Eleusine corocana*) associated with a forage plant (*Brachiaria sp.*, *Stylosanthes sp.*, *Cajanus cajan)* ; both cereals and forages plants are efficient “nutrient pumps”; furthermore forage crops produce a large biomass in the dry season and can be used as green fertilizer or cattle fodder (Figures 6 to 11).

As in forest ecosystems, the cereal + forage associations acting as a nutrient pump draw on deep soil water (at more than two metres) during the dry season. Furthermore, these associations have a great capacity of spontaneous regrowth during the erratic rains of the dry season and during the first rains of the wet season, thus guaranteeing a complete and permanent soil cover.

The total annual production of dry matter (above and below ground) rose from four to 8 t/ha in 1986 for initial systems producing one crop per year, to an average of more than 30 t/ha in 2000 for the best DMC on dead or live plant covers (Séguy *et al.,* 2001). Annual commercial production from the main crop can reach 4500 kg/ha of soybean or more than 6000 kg/ha of rice, between 1500 and 3000 kg of either maize, sorghum, millet or *Eleusine corocana* from the second crop and between 65 and 90 kg of meat in the dry season, from the forage crop.

In summary, sustainable management of soil and crops builds on the trilogy of DMC: no-tillage, abundant and permanent biomass above and below ground and the practice of crop rotations.

Application to cotton cropping: enhanced biodiversity, lower production costs, higher stability of productivity and profit

Recent research carried out over the last five years by CIRAD in partnership with Coodetec and Agronorte in the HTZ aims to optimise the management of soils and crops, including cotton, under DMC. Results show that very high cotton production can be sustained as long as veritable direct seeding systems are practised, in which:

1. Tillage is excluded (either to incorporate cotton residues or to sow early season cover crops and "safrinhas")
2. The cotton crop is inserted every two or three years within the framework of diversified rotations
3. A large amount of biomass is supplied by annual successions of soybean as main crop + maize or sorghum or millet as second crops associated with *Brachiaria ruziziensis* or soybean and *Eleusine corocana* as second crop (Figures 6, 7 and 12; Séguy *et al.,* 1997; 1998, 1999, 2002).

This type of management under diversified DMC permits the use of weaker doses of inputs (lime, fertilisers and pesticides), leading progressively to a fall in production costs to below 1000 US $/ha while maintaining very high yields, between 3500 and 5000 kg/ha of cotton-seed (Figures 13, 14 and 15).

The choice of cultivars should be made according to the biological quality of the soil, which is a result of the cropping system: rustic varieties (such as IAC 23 and 24) when the monoculture exerts heavy negative biological pressure, more sophisticated varieties with greater potential and a better quality of fiber (Fibermax 966, Coodetec 406 and Coodetec 407, Sure Grow 821) in the framework of diversified DMC (Figure 15).

Growing cotton as a second crop ("safrinha")

Cotton can also be grown as a second crop, succeeding either a short cycle variety of rice or soybean (main crop), or a high biomass producing cover crop (*Brachiaria ruziziensis*, *Eleusine coracana*) sown at the beginning of the wet season (Figures 8, 9 and 16).

A cotton "safrinha" can prove to be a very profitable economic choice so long as it is included in DMC producing highly nutritive biomasses (such as *Eleusine corocana,* sorghum or millet associated with *Brachiaria ruziziensis*). These biomasses build-up a fertility of organic-biological origin whose contribution to the soil's productive capacity increases with the passage of time (Séguy *et al*., 2001a). This soil management allows drastic reductions in the use of fertilisers (and pesticides) while high and stable yields are maintained. A cotton "safrinha" can thus produce between 2500 and 3000 kg/ha of cottonseed with very small quantities of fertilisers (35 to 60 kg/ha N + 40 kg/ha P_20_5 + 40 kg/ha K_20). With production costs being between 500 and 700 US$/ha, it becomes a profitable option with low economic risks (Figures 17 and 18; Séguy *et al.*, 2001b).

Among the cotton varieties best suited to "safrinha" conditions can be cited: Sicala 32, Coodetec 402 and promising new lines which exhibit higher yields and better fiber quality than current commercialised varieties (Séguy *et al.,* 2001b).

This spectacular progress of participatory innovation-extension research, obtained on some of the poorest soils in the world and under a particularly harsh climate, is the result of the concomitant optimisation of the management of both soil and genetic resources selected for and under DMC.

DMC specificity: simple, natural and low-cost solutions to resolve principal production nuisances.

DMC mimic the functioning of forest ecosystems: there is no tangible loss of nutrients ("closed circuit"); noxious effects of acidity (Al ions) on sensitive crops (soybean, maize, cotton) are efficiently neutralised, allowing drastic reduction in calcio-magnesium liming, i.e. example of the annual succession of soybean + maize associated with *Brachiaria ruziziensis* (Séguy *et al.,* 1999). The cover of Guinea sorghum perfectly controls the vegetable pest *Cyperus rotundus* in cotton crops on ferralitic soils on basalt (Figure 19) and efficiently disintoxicates them when polluted by the sulfentrazone molecule "*phytorémédiation*" (Figure 20; Séguy *et al.,* 1999).

Under diversified DMC, parasitic pressure on rainfed rice, soybean and cotton (due to cryptogamic diseases, bacterial blight, pests and nematodes) is significantly alleviated, resulting in an improved sanitary state of these crops. For instance, natural biological control of the soybean caterpillar *Anticarsia gemmatalis by* the pathogenic fungus *Nomuraea releyi* has been observed under DMC, probably due to higher biodiversity. The incidence of ramulosis on cotton (*Colletotrichum gossypii var. cephalosporioides)* is drastically reduced under DMC, probably due to better water infiltration rates avoiding waterlogging conditions favorable to fungi infection. Dung beetles, termites and ants play a role in the maintaining of a high soil macroporosity.

The impact of DMC on the soil's physical-chemical and biological properties and on soil-plant relationships (Figures 21 and 22)

Carbon losses under mono-cropping systems with tillage (soybean and cotton) were estimated over a five years period between 0.25 and 1.40 mg C ha-^{1}.year-^{1} depending on soil and climate conditions. Nevertheless, carbon gains can be as rapid as the losses and depend on the nature of the DMC practised. In this respect, the most efficient DMC are those including forage species (*Brachiaria ruziziensis*, *Eleusine corocona, Cynodon dactylon)* which grow actively during the dry season in the HTZ, supplying large amounts of above and underground dry matter; they lead, even over short periods of between three to five years, to the recovery of the SOC of the original ecosystems and can even exceed it. The annual sequestration of Carbon, over three to five years is between 0.83 and 1.50 mg C ha-^{1}.year-^{1} in the 0-10 cm top soil layer depending on the nature of the DMC, but can reach 1.40 to 1.80 mg C. ha-^{1}.year-^{1} in the 10-20 cm layer when forage species with stronger and deeper roots are used like *Brachiaria ruziziensis* and *B. brizantha*, *Eleusine corocana* (Séguy *et al.,* 2001a; Capillon and Séguy, 2002). These results are consistent with those obtained by Corraza *et al.* (1999) in the Cerrados region and in Amazonia (Cerri *et al.,* 1992). The evolution of the cationic exchange capacity (CEC) strictly follows that of carbon: the most effective DMC create a retention capacity for nutrients, which limits their leaching.

The DMC that are most effective in recharging the soil profile with organic carbon have also the highest capacity for recycling nutrients. They include either "safrinhas" cover crops (sorghum and millet associated with *Brachiaria ruziziensis, Stylosanthes guyanensis, Eleusine coracana* (alone or associated with *Cajanus cajan*), *C. cajan* (associated with *Brachiaria ruziziensis*) or forage species (*Brachiaria brizantha, Panicum maximum*) introduced as pastures for three to five year periods in alternation with cycles of grain and fiber production (process of crop – livestock integration). These nutrient pumps fulfil their recycling function at a depth of over 2 meters , as demonstrated by the numerous root profiles carried out over 15 years, which have shown very dense roots, up to 3 meters deep, beneath these species and their combinations (Séguy *et al.,* 2001a, 1997-2002 ; Capillon and Séguy, 2002). The significant rises in the bases saturation measured under these "nutrient pumps" on the 0-10 cm topsoil layer are very illustrative in this respect (Séguy *et al*., 2001a).

Furthermore, DMC have selective effects on soil, crops and their biological environment (including weeds and pests). For example, the leguminous plants *Stylosanthes guyanesis and Arachis pintoi* are particularly efficient in recycling potassium and the micronutrients Mn, Cu, Zn when they occupy a significant place in the rotation (Séguy *et al.,* 2001a). These results are consistent with Miyazawa *et al.* (2000) who have recorded selective effects on the dynamic of nutrients with diverse DMC. The best DMC not only build up carbon deep in the soil but are also extremely efficient in restructuring top soil (the 0-20cm layer): after five years, indicators of the structural state of the soil reach values close to the values recorded in the natural forest and savannah ecosystems (Séguy *et al.*, 2001a). Depending on the cover crop, it is now possible, after the chemical or mechanical desiccation of the biomass preceding the direct seeding, to drastically reduce or totally avoid herbicide use on main crops. Natural weed control, through the careful choice of the cover crop, constitutes a very important ecological alternative to the use of transgenic herbicide resistant cultivars. Best DMC for cotton are crop rotations with soybean or rice including cereals as second crops associated with forage crops growing in the dry season. Such results may lead to elaborate decision supports to help farmers in the choice and management of DMC.

Conclusion

The adoption of DMC has allowed Mato Grosso farmers to stop the cycle of accelerated degradation of soils resulting from monocultures under tillage, and enter into a cycle of the reconstruction of soil fertility. The scenario of sustainable agriculture, mimicking the functioning of the forest ecosystem, have been improved over the years from ecological, agronomic, technical and economic points of view. DMC offer to farmers all the necessary guarantees for a sustainable agriculture: higher productivity (more than 28-30 t/ha of biomass each year) with fewer chemical inputs and a higher biodiversity. Biomass production is maximised with diversified rotations including two or more crops per year (main crop + "safrinhas") with forage crops growing during the dry season. DMC offer diversified options for the integration of crop and livestock farming systems without tillage. Dead or live plant covers that are a source of intense biological activity provide permanent soil protection and load the topsoil with organic carbon, favouring the retention of nutrients (higher CEC). Powerful rooting crops draw on deep soil water and nutrients during the dry season, achieving a recycling process as effective as the forest ecosystem (closed-circuit functioning) and building up carbon deep in the profile.

Slowly, under difficult conditions, a class of highly competitive farmers has appeared and grown strong and is now ready to confront a global economy without subsidies. The HTZ of the Mato Grosso has become the Brazilian leader of productivity for soybean, rainfed rice and high-technology cotton. The priority must now be to focus on the training for and dissemination of the most efficient DMC, thus allowing farmers to produce more with less input, on sound soils completely protected from erosion, guaranteeing sustainability.

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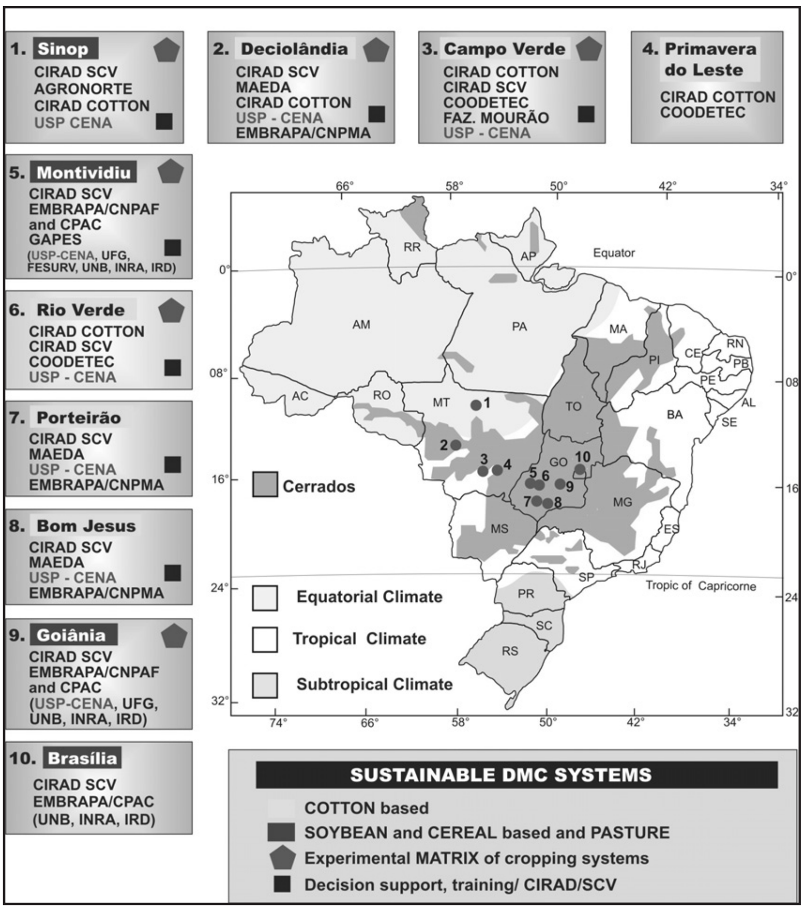


Figure 1. Brazilian network sustainable agriculture – intervention benchmark sites and partners.

Figure 2. *Estimated cotton yield losses due to erosion (cultivar IAC 22) - Fazenda Recanto – GO – 1995.*

	In between gullies of erosion		On the gullies of erosion		% of eroded area		Estimated losses (% ha)	
	Nº of bolls[2] /m.	Estimated yield kg/ha	Nº of bolls[2] /m.	Estimated yield kg/ha	Mid slope	Bottom slope	Mid slope	Bottom slope
Scarification	62	2100	43	1460	25	32	08	11
Conventional Tillage	45	1850	34	1290	36	40	12	14

(1) Estimations realized in the experimental unit (75 ha), on the toposequence - 12 repetitions of 50 m^2

(2) 8 repetitions of 10 m.

SOURCE: L. Séguy, S. Bouzinac - **CIRAD-CA**; **Maeda** - Itumbiara - GO, 1996

Figure 3. *An on-farm participatory innovation-extension method.*

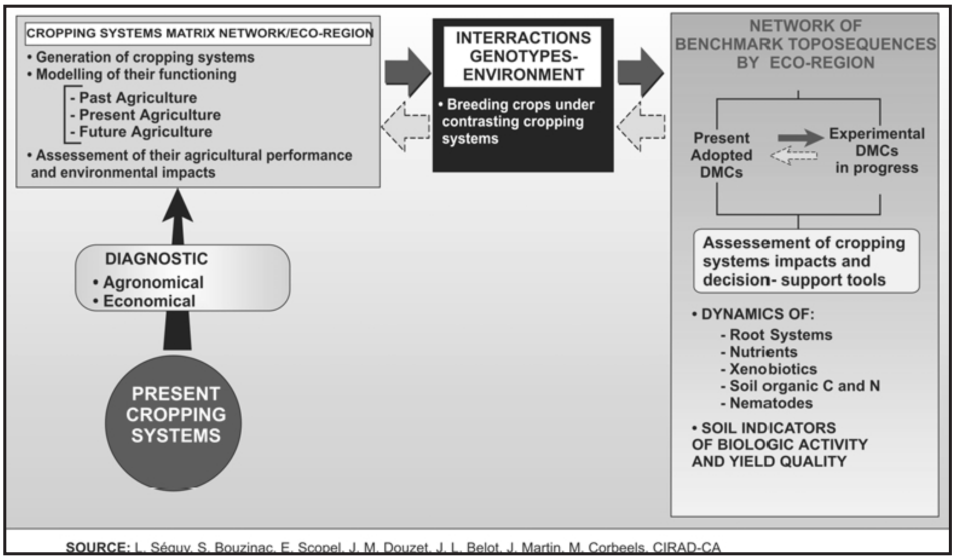


Figure 4. *Cotton DMC systems in tripical forest ecosystems of South Goias State, mina Gerais, Noth of Sao Paulo and mumid forest and Cerrado ecosystem of Mato Grosso.*

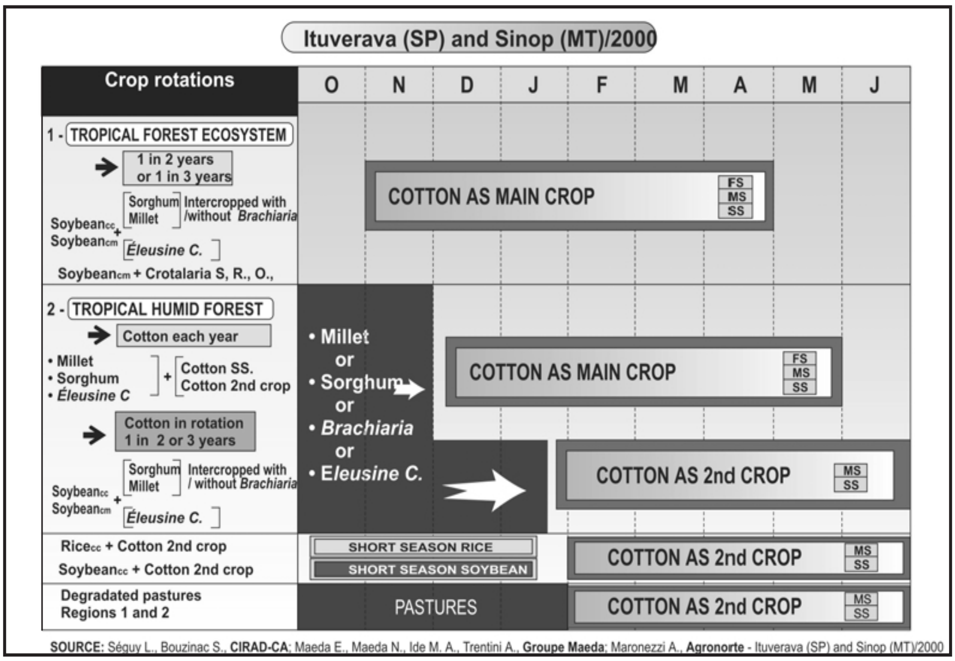


Figure 5. *Estimated costs for high yielded cotton with minimum tillage practices.*

Maeda Group - Fazenda Guapirama - Deciolândia, MT - 2001

	Costs (US$/ha)	% total cost
1. LAND PREPARATION AND COVER CROP		
• Limestone	5,5	
• Tillage + sowing Sorghum	47,8	
• Herbicides	13,6	
• Operational cost	5,5	
Sub total	72,4	4%
2. SOWING		
• Seed treatment (12 kg/ha)	37,6	
• Fertilizers 4-30-16 (450 kg/ha)	114,8	6,8%
• Herbicides (2 lit. Cention + 1,8 lit. Gamit)	47,1	
• Operational cost	9,2	
Sub total	208,7	12,4%
3. GROWING PERIOD		
• Herbicides	87,7	
• Fertilizers	234,9	14%
• Insecticides	182,8	10,8%
• Fongicides	64,8	
• Growth regulatores + Defoliants	29,7	
• Operational cost	81,6	
Sub total	681,5	40,6%
4. MECANICAL HARVEST (0,58 US$/@)	290 @c.g. 168,0	100%
5. TRANSPORT (0,113 US$/@) • Until ginning = 33,1 • Fiber trading = 120,3	153,4	9,0%
6. GINNING (with cottonseed trading)	114,5 @/Fi. 62,5	3,7%
7. ECONOMICAL COSTS	80,8	4,8%
8. FIX COSTS		
• Land hire	67,5	
• Employees costs	71,8	
• Operational costs	67,1	
• Insurance	44,7	
• Sub total	251,1	4,8%
9. TOTAL COSTS	1.678,5	
10. YIELD TO COVER PRODUCTION COSTS	109,5 @ fibre	or 277@ c./ha with 39,5% g t.o

(*) Price = 0,46 US$/Pound Cotton fiber (or 15,33 US$/@ fiber)

SOURCE: MAEDA - Deciolândia/MT, 2001

Figure 6. *Direct seeding on dry mulch and life cover crop.*

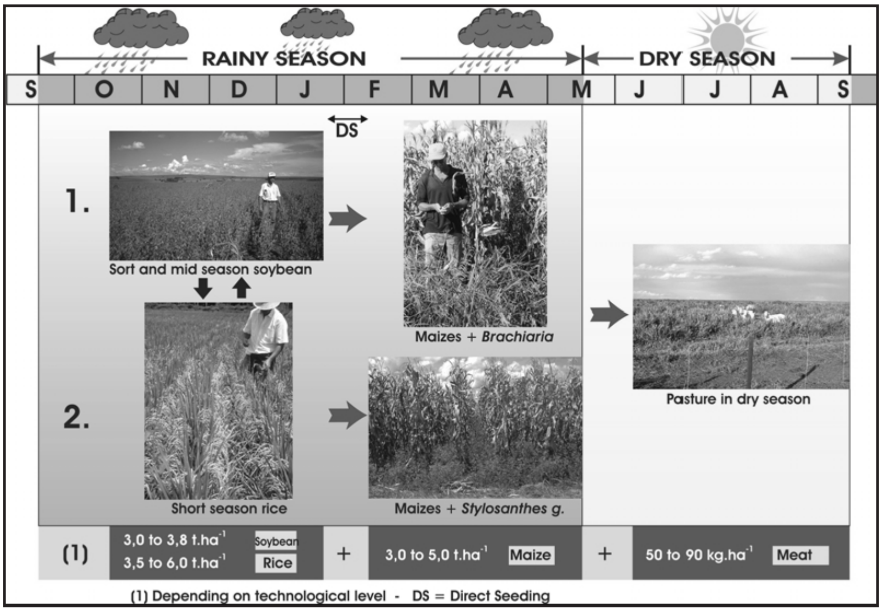


Figure 7. *Direct seeding on dry mulch and life cover crops (contn'd).*

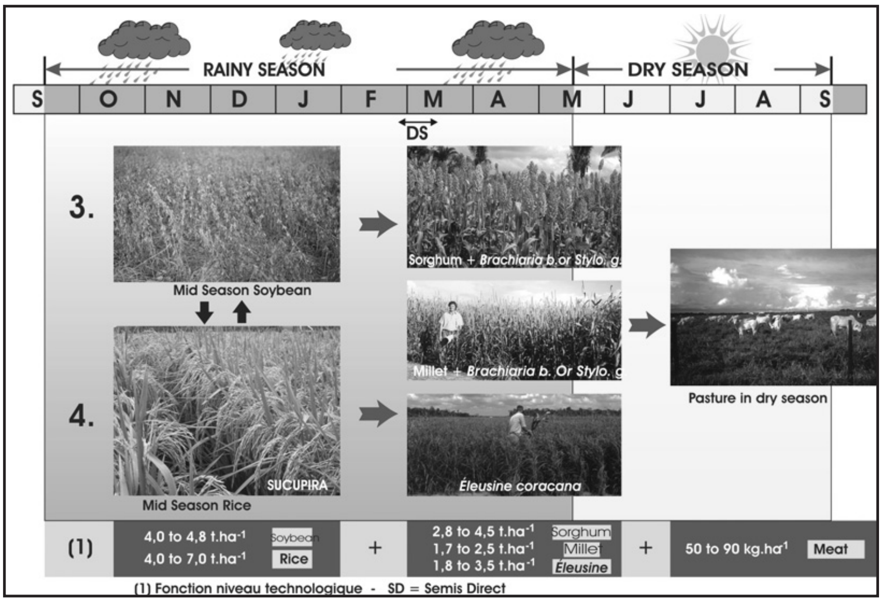
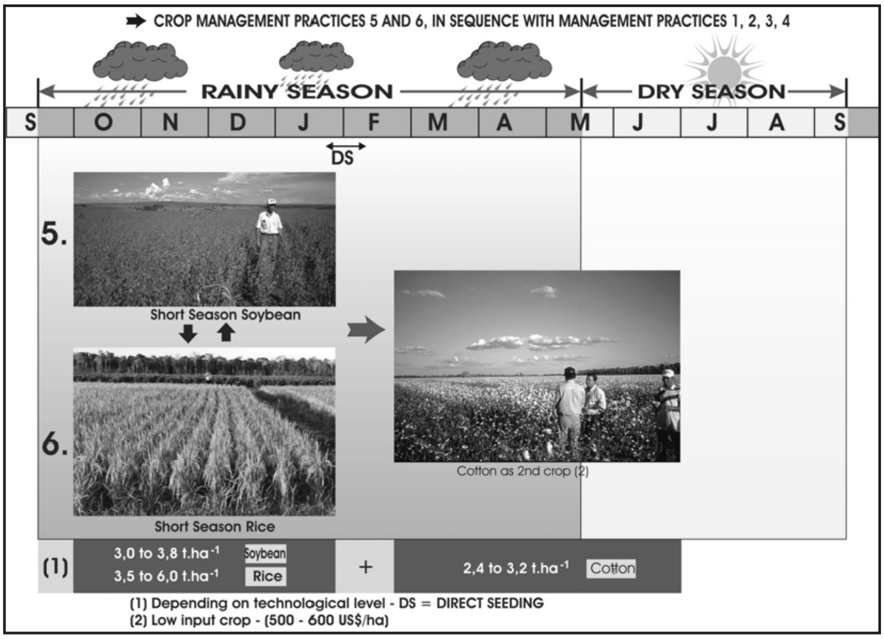


Figure 8. *Direct seeding on mulch of crop residues (contn'd).*



Figue 9.
Direct seeding on mulch of crop residues (contn'd).

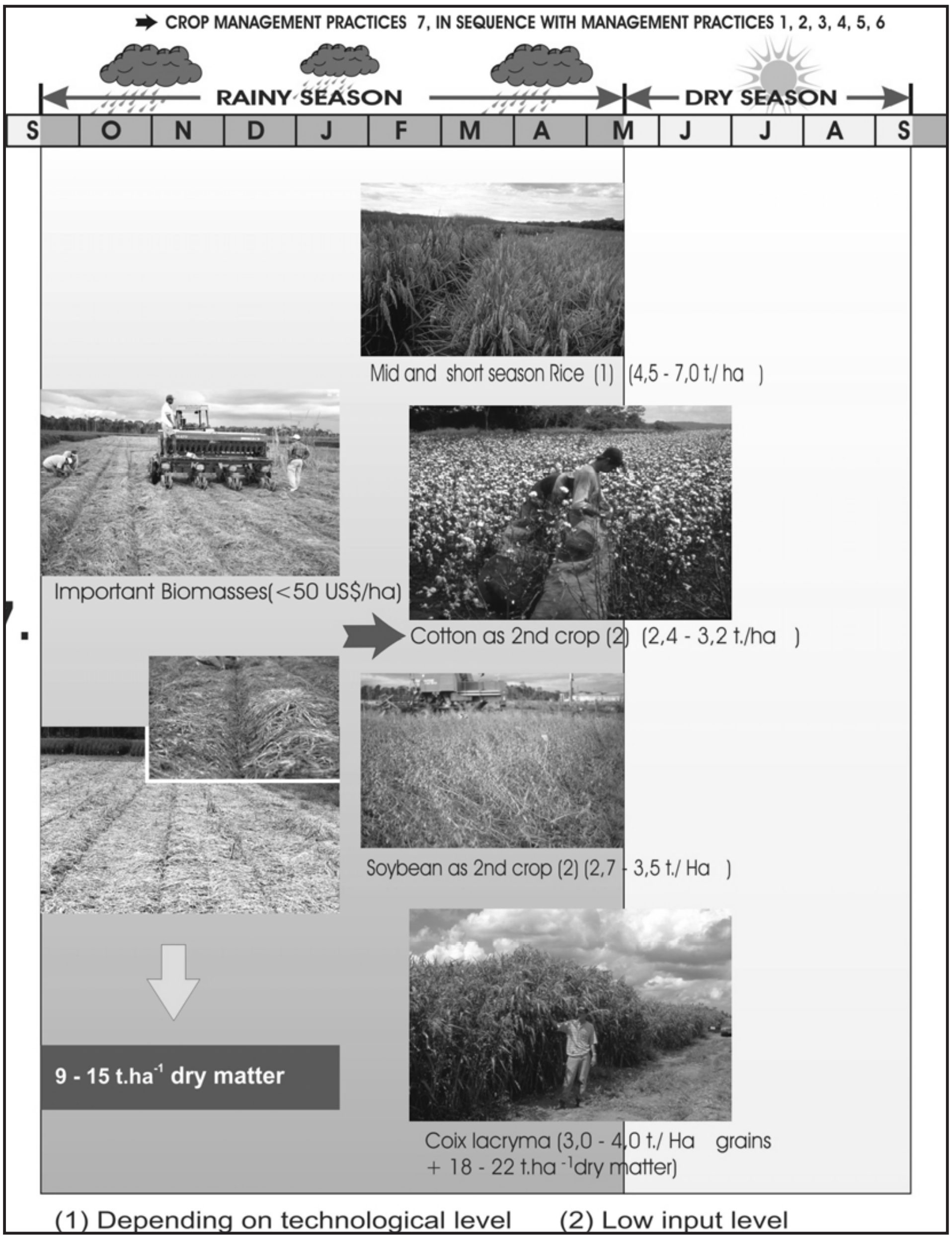


Figure 10. *Direct seeding on life cover crop (contn'd).*

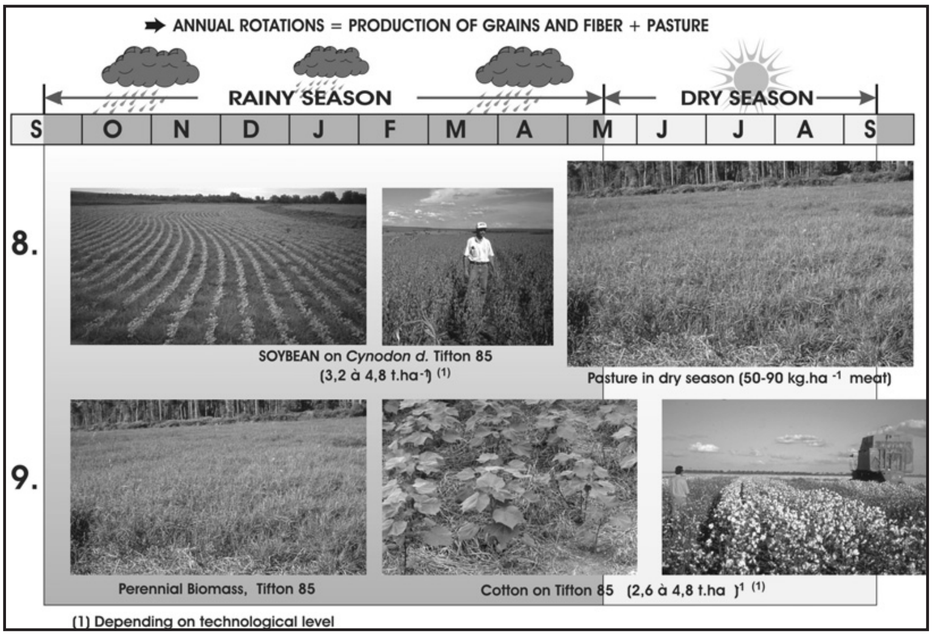


Figure 11. *Direct seeding on life cover crop (contn'd).*

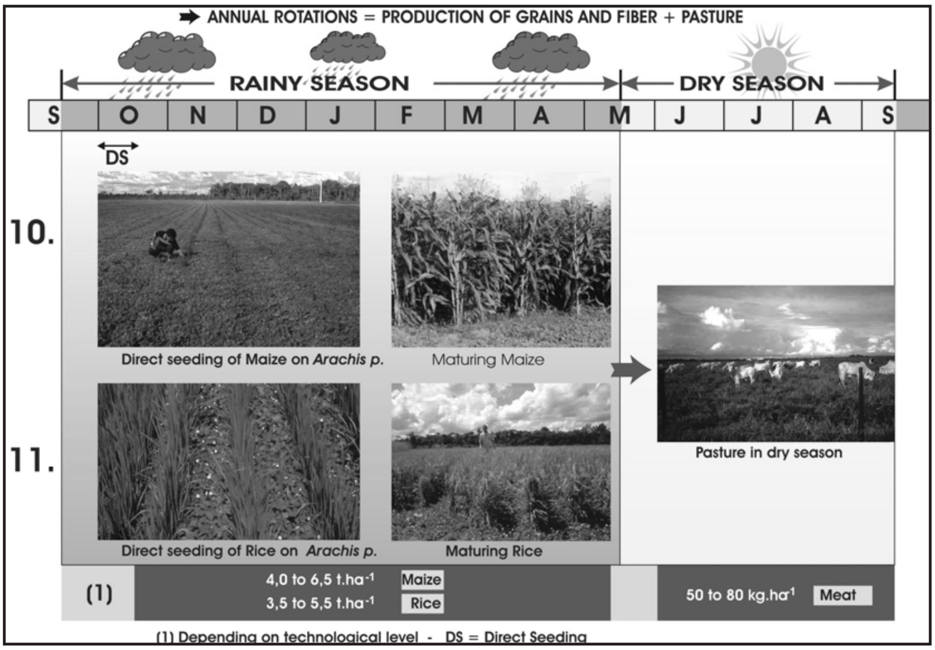


Figure 12. *Diversified DMC systems in the tropical humid region (mixed cropping – livestock farming).*

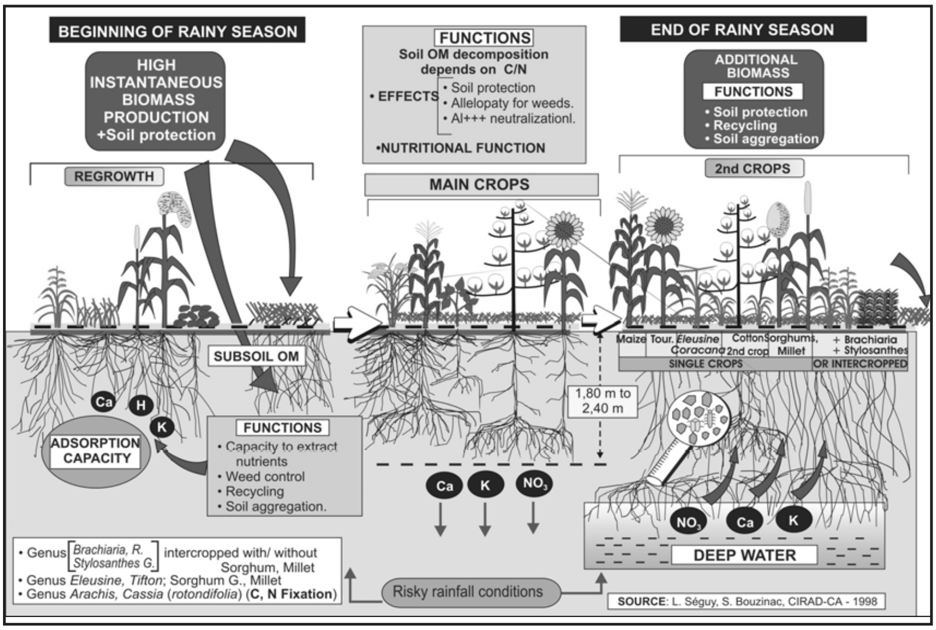


Figure 13. *Yield of several cotton varieties with two DMC systems (with sorghum and Crotolaria) in two localities of the Mato Grosso State (Campo Verde and Campo Novo dos Parecis).*

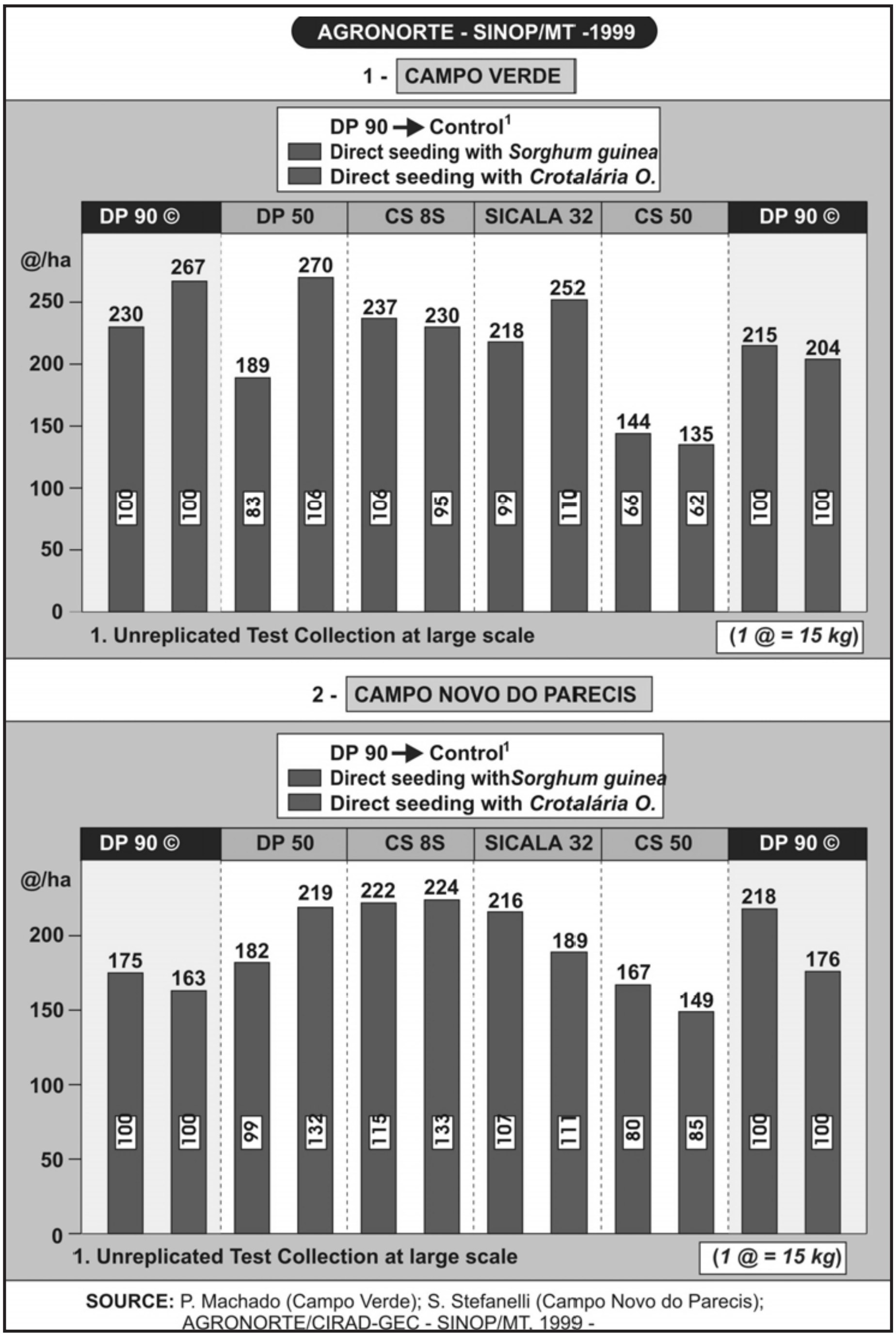


Figure 14. Performances of cotton varieties with DMC systems on large-scale farming (6 ha/ variety) in relation to mineral fertilization.

Fazenda Guapirama - Deciolândia/MT, 2001

VARIETY	Fertilization level	Pl. Nb /m	(CV%)	Boll Nb. /m	(CV%)	Weight/boll g	(CV%)	@ Cottonseed [4] /ha	(CV%)	Ginning t.out %	@ fiber[4] /ha
COODETEC 404	1	7,2	(30)	58,8	(10)	5,97	(3)	234	(11)	38,8	91
	2	8,9	(20)	66,1	(10)	5,89	(4)	259	(8)	39,1	101
DELTA OPAL (Control)	1	9,0	(5)	73,4	(9)	5,18	(3)	254	(11)	42,2	107
	2	8,1	(24)	71,4	(12)	5,28	(6)	250	(10)	42,0	105
FIBERMAX 966	1	8,4	(20)	67,5	(11)	5,96	(4)	268	(12)	42,7	115
	2	9,6	(17)	66,6	(10)	5,80	(4)	257	(11)	42,3	109
SATURNO FMT 122	1	6,6	(18)	53,2	(14)	6,37	(5)	225	(13)	39,5	89
	2	6,9	(14)	57,7	(10)	6,28	(5)	241	(11)	39,6	95
FIBERMAX 986	1	7,4		56,3		6,0		226		38,7	88
IAC 97/86	1	8,2		59,3		6,3		247		37,7	93
COODETEC 402	1	7,05		64,4		5,8		249		39,0	97

1. $150N + 177P_2O_5 + 246\ K_2O$ = Level recommended by O. Martins (+ *oligo-elements*)
2. $150N + 120P_2O_5 + 175\ K_2O$ = Level recommended by L. Séguy (+ *foliar oligo-elements*)
3. DMC with Sorghum IRAT321 biomass
4. Calculated yield

SOURCE: L. Séguy, S. Bouzinac, CIRAD-CA/GEC - E. Maeda, M. A. Ide, W. Okabe, M. Morita, GROUPE MAEDA-MT, 2001

Figure 15. Performance of cotton varieties with DMC systems in relation to type of crop rotations (Ferrallitic soils of the humid Cerrados of west Mato Grosso).

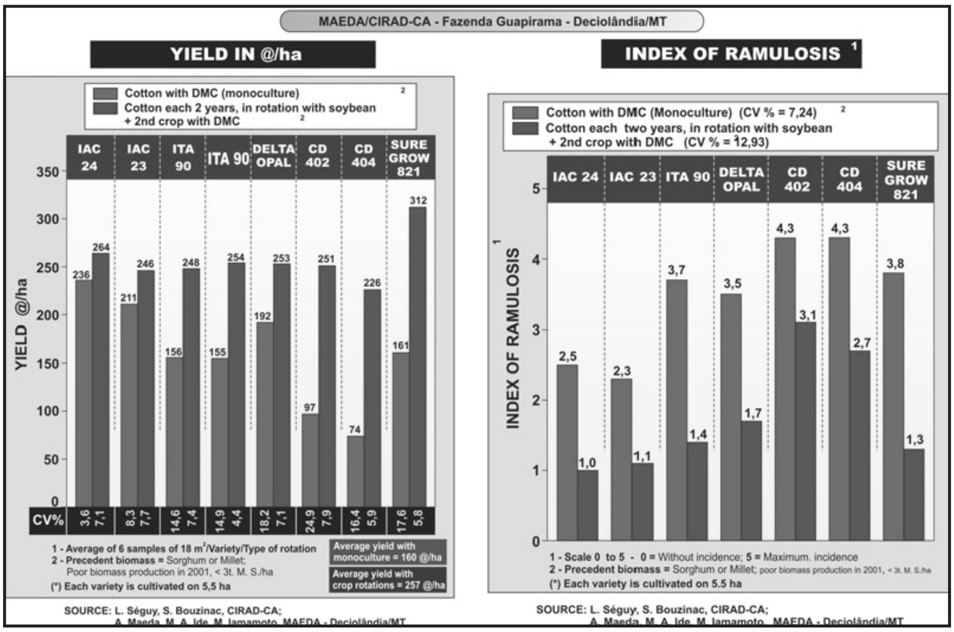


Figure 16. Technical management options for cotton as second crop in tropical humid regions.

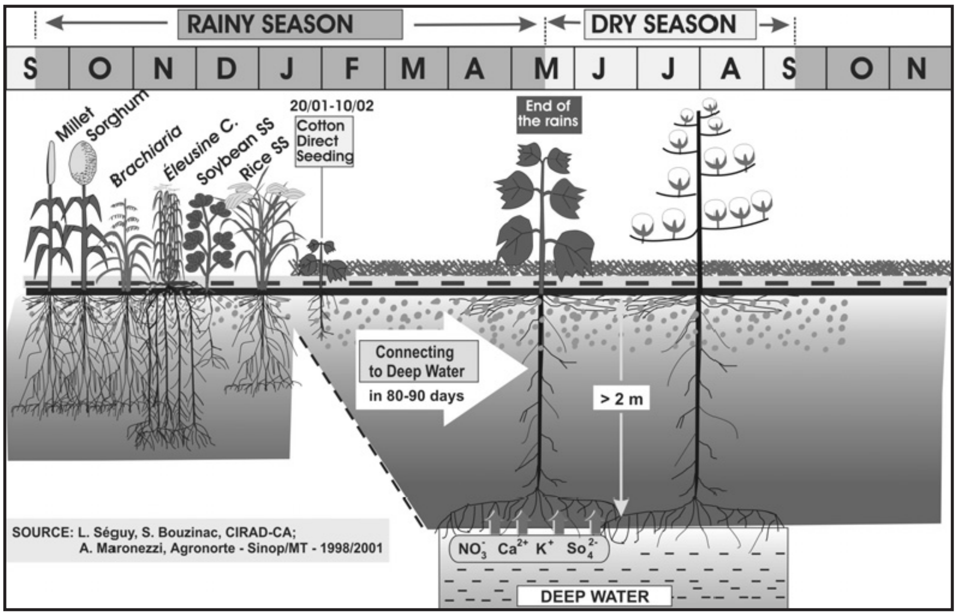


Figure 17. Performance of the best cotton varieties with DMC – Forest ecosystems of the central-north of Mato Grosso.

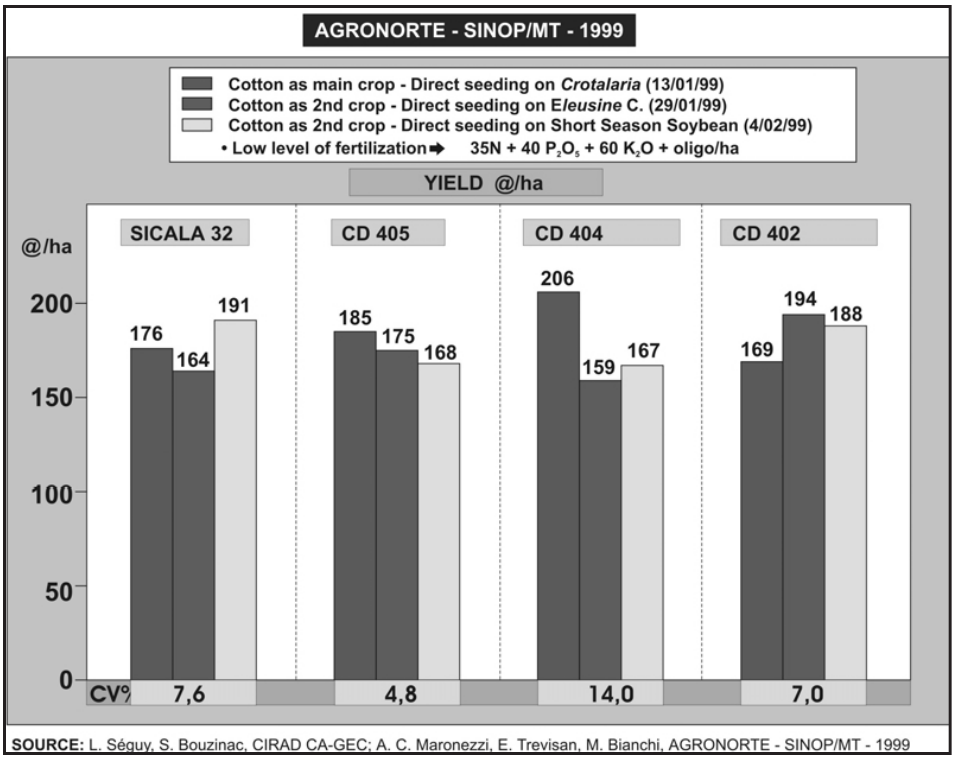


Figure 18. Performance of the best cotton varieties with DMC – Forest ecosystems of the central north of Mato Grosso.

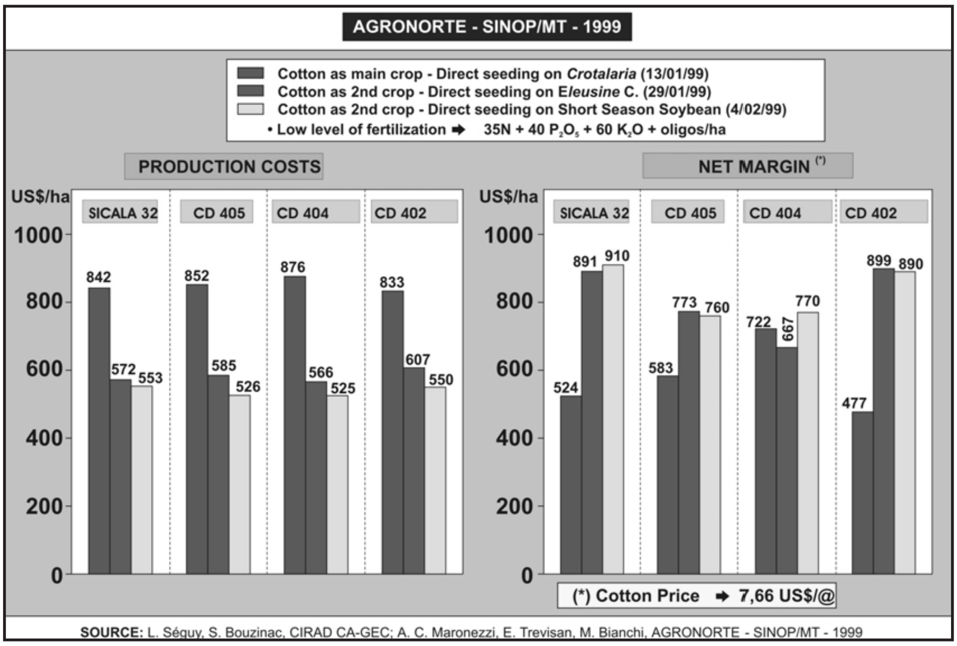


Figure 19. Control of Cyperus rotondus *with DMC systems (Red Ferrallitics soils on basaltic rock – Ituverava, SP – 1998).*

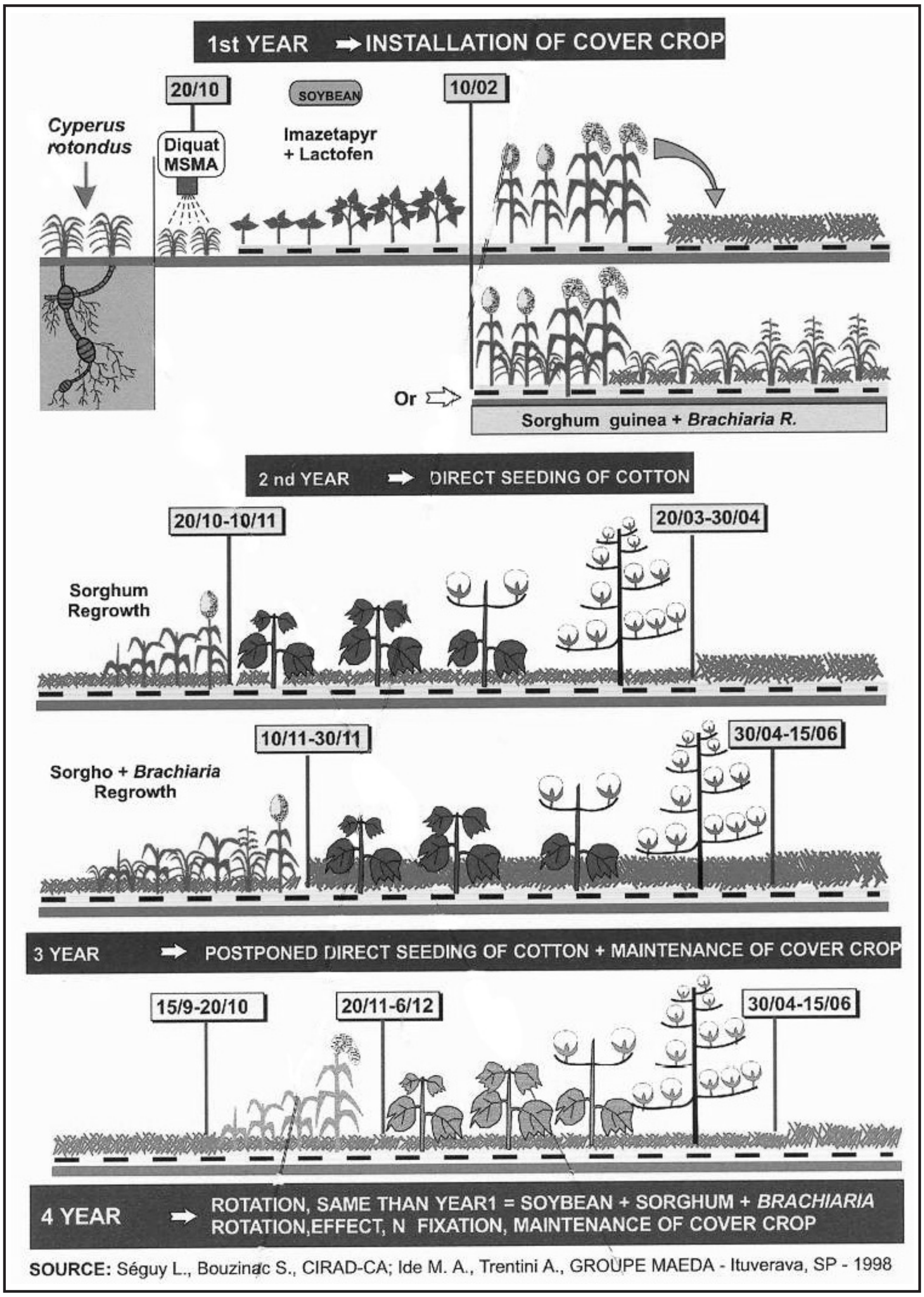


Figure 20. Detoxification of polluted soil with Boral herbicide by several cover crops in DMC systems.

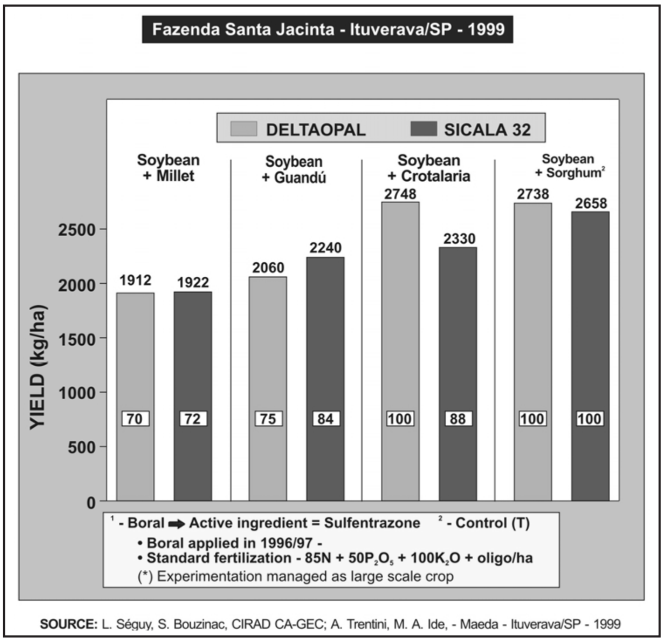


Figure 21. Summary of evolution of soil organic matter (SOM) (in mg C ha-1), in relation to the type of cropping system.

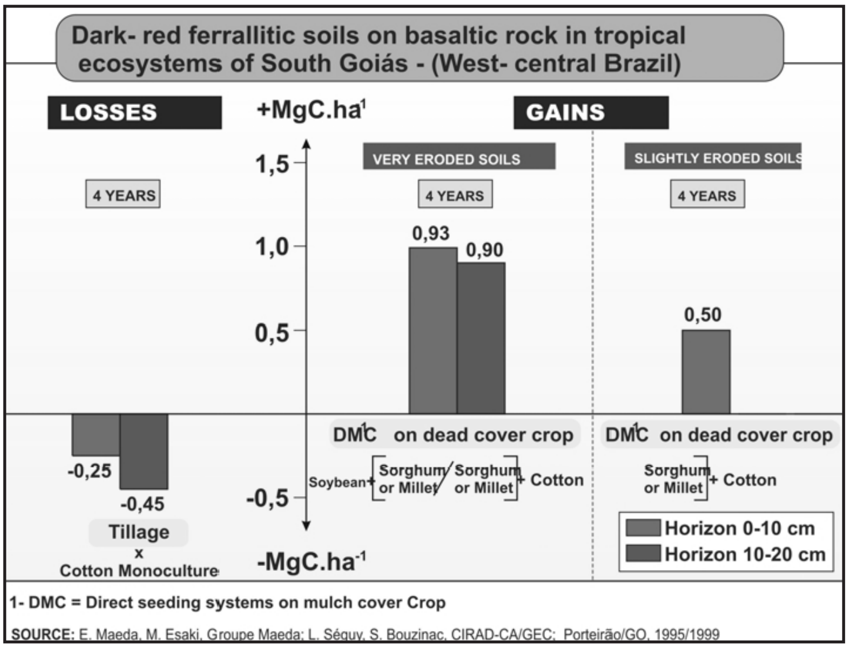


Figure 22. Summary of evolution of soil organic matter (SOM) (in mg C ha-1), in relation to the type of cropping system.